RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)

DATE: February 2000

BUDGET ACTIVITY: 02 - Applied Research

PE NUMBER AND TITLE: 0602601F Space Technology

	COST ($ in Thousands)	FY 1999 Actual	FY 2000 Estimate	FY 2001 Estimate	FY 2002 Estimate	FY 2003 Estimate	FY 2004 Estimate	FY 2005 Estimate	Cost to Complete	Total Cost
	Total Program Element (PE) Cost	122,170	146,021	57,687	54,495	55,743	62,943	69,602	Continuing	TBD
621010	Space Systems Protection Technology	24,351	21,596	18,290	11,646	11,641	16,473	17,935	Continuing	TBD
621011	Rocket Propulsion Technology	33,594	41,600	0	0	0	0	0	Continuing	TBD
623326	Lasers and Imaging Technology	15,614	19,039	0	0	0	0	0	Continuing	TBD
624846	Spacecraft Payload Technologies	0	0	8,395	11,785	10,499	9,866	13,918	Continuing	TBD
625797	Advanced Weapons and Survivability Technology	14,730	18,530	0	0	0	0	0	Continuing	TBD
628809	Spacecraft Vehicle Technologies	33,881	45,256	31,002	31,064	33,603	36,604	37,749	Continuing	TBD
	Quantity of RDT&E Articles	0	0	0	0	0	0	0	0	0

Note: In FY 2001, spectral sensing (intelligent satellite systems and hyperspectral technology) efforts in Project 623326 move into Project 628809. In FY 2001, in order to align projects within the Air Force Research Laboratory organization, all rocket propulsion efforts performed in Project 621011 were transferred to PE 0602203F, Project 624847, and all lasers and imaging efforts in Project 623326 and all advanced weapons and survivability technology efforts in Project 625797 were transferred to PE 0602605F, Projects 624866 and 624867. In FY 2001, Project 628809 has been split with spacecraft payload technology being moved into Project 624846. In FY 2001, the satellite protection related work currently in Project 628809 moves into Project 621010.

(U) A. Mission Description

This is the Applied Research program for geophysics, space, and directed energy technologies for the Air Force Research Laboratory. In geophysics, this PE develops technologies to understand, mitigate, and exploit effects of weather and geophysics environments on the design and operation of Air Force systems. This includes defining, modeling, and developing techniques to predict the phenomena of solar and space environments. In lasers, this PE examines the technical feasibility of moderate to high power lasers, associated optical components, and long-range optical imaging concepts required for Air Force missions. Technologies researched include high power solid state and chemical laser devices, optical components, advanced beam control and atmospheric compensation technologies, techniques for laser target vulnerability assessments, and nonlinear optics processes and techniques. Advanced weapons examines high power microwave and other unconventional weapon

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(U) A. Mission Description Continued

concepts using innovative technologies such as compact toroids. This also provides for vulnerability assessments of representative U.S. strategic and tactical systems to directed energy weapons, directed energy weapon technology assessment for specific Air Force missions, and directed energy weapon lethality assessments against foreign targets. Spacecraft payload technologies focus on the improvement of satellite payload operation by improving component and subsystem capabilities. This project concentrates on development of advanced, space-qualified, survivable electronics and electronics packaging technologies, advanced space sensors and satellite antenna technologies, and high fidelity space simulation models to support space-based surveillance and space asset protection technologies. In space and missiles, this PE contains the following technologies: spacecraft platform (e.g., structures, controls, power, and thermal management); space-based payload (e.g., sensors, satellite communications, and survivable electronics); satellite control (e.g., spacecraft software); ballistic missile/launch vehicle-specific (e.g., astrodynamics and guidance, navigation, and control avionics); and integrated experiments of advanced technologies for transition to planned systems (e.g., payload/platform/launch vehicle merging). Note: In FY 2000, Congress added $10.0 million for the High-frequency Active Auroral Research Program, $5.0 million for the Terabit fiber optic technology program, $2.0 million for Post Boost Control Systems, $1.2 million for missile propulsion technology, $2.5 for radio frequency (RF) applications development, $2.3 million for tactical missile propulsion, $2.8 million for Integrated High Payoff Rocket Propulsion Technology, $1.7 million for orbit transfer propulsion, $2.5 million for tropo-weather, $0.6 million for space survivability, $4.5 million for hyperspectral imaging, $0.6 million for hyperspectral sensing, $0.8 million for space optics relay mirror concept, and $1.2 million for laser remote optical sensing.

(U) B. Budget Activity Justification

This program in Budget Activity 2, Applied Research, since it develops and determines the technical feasibility and military utility of evolutionary and revolutionary technologies.

(U) C. Program Change Summary ($ in Thousands)

		FY 1999	FY 2000	FY 2001	Total Cost
(U)	Previous President's Budget (FY 2000 PBR)	125,585	115,313	110,811	
(U)	Appropriated Value	129,139	147,118		
(U)	Adjustments to Appropriated Value				
	a. Congressional/General Reductions	-3,554	-73		
	b. Small Business Innovative Research	-2,632			
	c. Omnibus or Other Above Threshold Reprogram		-546		
	d. Below Threshold Reprogram	-101			
	e. Rescissions	-682	-478		
	f. Other				TBD
(U)	Adjustments to Budget Years Since FY 2000 PBR			-53,124	
(U)	Current Budget Submit/FY 2001 PBR	122,170	146,021	57,687	TBD

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(U) C. Program Change Summary ($ in Thousands) Continued

(U) Significant Program Changes:
Changes to this program since the previous President's Budget are due to Program Element and Project realignment.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2A Exhibit)

DATE: February 2000

BUDGET ACTIVITY: 02 - Applied Research

PE NUMBER AND TITLE: 0602601F Space Technology

PROJECT: 621010

COST ($ in Thousands)	FY 1999 Actual	FY 2000 Estimate	FY 2001 Estimate	FY 2002 Estimate	FY 2003 Estimate	FY 2004 Estimate	FY 2005 Estimate	Cost to Complete	Total Cost
621010 Space Systems Protection Technology	24,351	21,596	18,290	11,646	11,641	16,473	17,935	Continuing	TBD

(U) A. Mission Description

This project develops the technologies to exploit the aerospace environment to the warfighter's benefit. The project focuses on characterizing the battlespace environment for realistic space system design, modeling, and simulation. It includes technologies to specify and forecast the environment 'mud to sun' for planning operations and ensuring uninterrupted system performance. Finally, it includes technologies that allow the opportunity to mitigate or exploit the aerospace environment for both offensive and defensive operations.

(U) FY 1999 ($ in Thousands)

(U) $4,400 Validated models and decision aids for specifying and forecasting space environmental hazards such as plasma hazards to satellite systems. Continued development of hardware and software for the Improved Solar Optical Observation Network (ISOON) system.

(U) $5,683 Explored and developed techniques to detect and track low-signature ballistic and cruise missiles and to optimize design of new surveillance sensors, including hyperspectral sensors. Explored instruments and techniques to detect theater ballistic missiles through clouds, haze, smoke, and dust to optimize the performance of operational laser weapon systems.

(U) $5,526 Defined and developed systems such as the space-based Communications/Navigation Outage Forecasting System (C/NOFS), sensors, and decision aids to measure, specify, and predict the effects of ionospheric disturbances on the operation of DoD space systems.

(U) $8,742 Expanded the infrastructure at the High Frequency Active Auroral Research Program's (HAARP) Alaska facility through construction of a control center and installation of radio and optical diagnostic instruments. Used the HAARP facility to assess new concepts for imaging underground structures and to generate ionospheric irregularities and high frequency sources for evaluation of their efforts on military space communication, surveillance, and navigation systems.

(U) $24,351 Total

(U) FY 2000 ($ in Thousands)

(U) $2,930 Develop technologies for monitoring, predicting, and controlling space environmental conditions hazardous to DoD operational space systems. Leads to improved space system design, lifetime, and operational capabilities and aid in anomaly resolution. Demonstrate on-orbit hazardous radiation monitoring using miniaturized radiation sensing technology. Complete analysis of interaction of transmitted radio waves with radiation belts to assess potential for mitigation of hazardous radiation levels.

(U) $2,489 Develop real-time infrared background clutter code, target detection techniques, and decision aids for application to space-based surveillance, laser weapons, and countermeasure systems, including detection of low-observable targets. Complete all-altitude background clutter prediction

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2A Exhibit)		DATE February 2000
BUDGET ACTIVITY 02 - Applied Research	PE NUMBER AND TITLE 0602601F Space Technology	PROJECT 621010

(U) A. Mission Description Continued

(U) FY 2000 ($ in Thousands) Continued

code to extend capability to all lines-of-sight for space-based sensors to support design of next generation surveillance satellites. Complete measurements of the visibility of surrogate missile target signatures through clouds to support earliest warning of missile launches. Perform measurements of atmospheric optical turbulence in theaters of interest, and develop deployment aids and performance prediction models to minimize operational impacts of optical turbulence on laser weapons. Validate atmospheric turbulence effects on operational laser systems.

(U) $2,618 Provide forecasts of outages of communication and navigation systems caused by ionospheric scintillation. This forecasting capability will support the warfighter through situational awareness, allowing operators to use alternate links or systems in times of outages. Design, fabricate, and begin test of Communications/Navigation Outage Forecasting System (C/NOFS) planar Langmuir probe sensor for measuring ionospheric plasma levels. Begin design and fabrication of neutral wind sensor for C/NOFS.

(U) $9,897 Expand experimental research capabilities to characterize and control the physical processes produced in space via interactions with very high power radio waves at the High Frequency Active Auroral Research Program's (HAARP) Alaska facility. Focus experimental research to assess concepts for imaging underground structures, providing new radio wave propagation modes via the generation of irregularities in the ionosphere, and for characterizing the space weather environment under both normal and naturally disturbed conditions. Transfer the operations center at HAARP facility from a temporary to a modern control center. Install additional on- and off-site diagnostic instruments. Develop software to provide real-time access to diagnostic data via the internet. Support basic, exploratory development, and related applications.

(U) $2,474 Develop software to predict impacts of weather on precision-guided munitions (PGMs) and navigation and surveillance systems and to predict weather effects uniquely impacting DoD military operations. Develop and transition: target acquisition weather software which provides pilots with PGM target detection and lock-on ranges; night vision goggles (NVG) operations weather software which provides pilots with NVG detection ranges; weather automated mission planning software; infrared target-scene simulation software; and contrail and cloud forecasts software.

(U) $594 Develop algorithms to facilitate the military applications of spectral detection from space with emphasis on target detection and terrain classification. Hyperspectral imaging will allow improvements and new capabilities in target detection, terrain classification, and other surveillance tasks using space-based surveillance assets. Develop and validate atmospheric compensation and image analysis algorithms needed to exploit data collected by space-based hyperspectral sensors. Adapt backgrounds data processing system to support analysis and exploitation of data collected by space-based hyperspectral sensors to assess military utility of space-based hyperspectral sensors.

(U) $594 Perform measurements to quantify effects of current solar cycle maximum on Global Positioning System (GPS) navigation links, developing associated algorithm for specifying GPS link outages, and upgrade and validate ionospheric effects specification model. Specification of outages to GPS navigation links caused by ionospheric scintillation will allow operators to select alternate systems and will provide situational awareness of degraded accuracy of GPS. Improved and validated ionospheric specification provides increased situational awareness for GPS navigation

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BUDGET ACTIVITY 02 - Applied Research	PE NUMBER AND TITLE 0602601F Space Technology	PROJECT 621010

(U) A. Mission Description Continued

(U) FY 2000 ($ in Thousands) Continued

accuracy, communications outages, high frequency communications connectivity, errors and clutter on surveillance radars, and geo-location accuracy. Develop GPS outage nowcasting system using ground-based sensors and advanced algorithms that include effect of solar cycle. Develop assimilation model for ionospheric specification that uses real-time data from ground and space sensors and is upgradeable to a forecasting capability.

(U) $21,596 Total

(U) FY 2001 ($ in Thousands)

(U) $5,578 Develop technology to predict space environmental hazards, including solar disturbances and the earth's radiation belts, and the resultant disruptions of operational space systems. Develop technology to control hazardous space particle populations in extreme environments resulting from natural or adversary actions. Begin algorithm development for predicting solar disturbances impacting Air Force systems using all-sky images from new space-based detector system. Develop time-dose probability codes for improved space system design using data from new compact environment anomaly sensors. Begin detailed design of active space particle control experiment to demonstrate feasibility of space-based mitigation technologies.

(U) $4,211 Develop real-time infrared background clutter code, target detection techniques, and decision aids for application to space-based surveillance, laser weapons, and countermeasure systems, including detection of low-observable targets. Validate all-altitude background clutter prediction code using space-based sensor data. Complete deployment aids and performance prediction models to minimize operational impacts of atmospheric optical turbulence on laser weapons. Complete assessment of advanced missile detection technologies for earliest detection of theater ballistic missiles in boost phase.

(U) $6,428 Develop artificial intelligence techniques, forecasting tools, and sensors for improved ionospheric specification and forecasting, including communications/navigation outage forecasting and space-based geo-location demonstrations. Communications/navigation outage forecasting will provide the warfighter with situational awareness and will permit operators to use alternate links or systems in times of outages. Complete the fabrication and test of instrumentation for communication/navigation outage forecasting system demonstration. Develop algorithms for correcting ionospheric effects on geo-location accuracy.

(U) $2,073 Develop key satellite threat warning technologies and tools for on-board satellite use to detect, geolocate, and characterize acquired intentional and unintentional ground-based radio frequency and laser signals. Satellite threat warning technologies enable the warfighter to increase knowledge of possible hostile acts directed at mission critical satellites and aid in satellite anomaly resolution. Design key satellite protection technologies such as geo-location algorithms, radio frequency antennas, laser sensors, and miniaturized sensor and processing electronics for advanced satellite threat warning/attack reporting capabilities. Produce brassboard low-power and lightweight laser detector for bench-level testing.

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BUDGET ACTIVITY 02 - Applied Research	PE NUMBER AND TITLE 0602601F Space Technology	PROJECT 621010

(U) A. Mission Description Continued

(U) FY 2001 ($ in Thousands) Continued
(U) $18,290 Total

(U) B. Project Change Summary

Not Applicable.

(U) C. Other Program Funding Summary ($ in Thousands)

(U) Related Activities:
(U) PE 0305160F, Defense Meteorological Satellite Program.
(U) PE 0601102F, Defense Research Sciences.
(U) PE 0602204F, Aerospace Sensors.
(U) PE 0603410F, Space Systems Environmental Interactions Technology.
(U) PE 0305111F, Weather Systems.
(U) PE 0603707F, Weather Systems Advanced Development.
(U) This project has been coordinated through the Reliance process to harmonize efforts and eliminate duplication.

(U) D. Acquisition Strategy

Not Applicable.

(U) E. Schedule Profile

(U) Not Applicable.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2A Exhibit)

DATE: February 2000

BUDGET ACTIVITY: 02 - Applied Research

PE NUMBER AND TITLE: 0602601F Space Technology

PROJECT: 621011

COST ($ in Thousands)	FY 1999 Actual	FY 2000 Estimate	FY 2001 Estimate	FY 2002 Estimate	FY 2003 Estimate	FY 2004 Estimate	FY 2005 Estimate	Cost to Complete	Total Cost
621011 Rocket Propulsion Technology	33,594	41,600	0	0	0	0	0	Continuing	TBD

(U) A. Mission Description

The technologies developed in this project are boost and orbit transfer, satellite maneuvering, and tactical and ballistic missile rocket propulsion. This project develops technologies and provides technology options for rocket propulsion advanced demonstrations, components, or subsystems. Technologies of interest are those which will improve reliability, operability, survivability, affordability, environmental compatibility, and performance of future space and missile launch sub-systems while reducing material, manufacturing, and support costs. Technology will be developed to reduce the weight and cost of components using new materials, improved designs, and improved manufacturing techniques. All efforts in this project are part of the Integrated High Payoff Rocket Propulsion Technology (IHPRPT) initiative; a joint Department of Defense, National Aeronautics and Space Administration (NASA), and industry effort to focus rocket propulsion technology on national needs.

(U) FY 1999 ($ in Thousands)

(U) $5,338 Continued to develop propellants with high-energy density for increased payload capability and lower cost space launch systems.

(U) $3,146 Continued developing advanced combustion technology for improved performance and reliability of engines used in heavy lift vehicles.

(U) $3,975 Developed advanced material technology for lightweight components and material property enhancement to decrease cost per pound to orbit particularly for reusable systems.

(U) $10,858 Continued to develop propulsion component technology for reliable, safe, and low-cost boost and orbit transfer systems. Developed solid and hybrid rocket propulsion technologies for upperstage and air launched missiles; both of the latter are part of international agreements.

(U) $7,000 Continued to develop technologies for long-term sustainment of strategic systems that also apply to the development of the next generation booster.

(U) $3,277 Developed solar electric and solar thermal propulsion technologies for stationkeeping, repositioning, and orbit transfer appropriate for large communication satellites and satellite constellations.

(U) $33,594 Total

(U) FY 2000 ($ in Thousands)

(U) $4,940 Continue to develop high-energy density and non-toxic propellants for increased payload capability. Continue to develop promising propellants to transition into future high-performance boost and orbit transfer propulsion systems. Optimize source for producing most favorable high-energy density additives and develop techniques to accurately measure concentrations of these additives to achieve cryogenic propellants that will maximize future propulsion system performance. Continue preparation for demonstrations and transitioning additives into system-ready applications. Continue to characterize, study/evaluate injector performance with application to combustor chamber/injector compatibility to

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(U) A. Mission Description Continued

(U) FY 2000 ($ in Thousands) Continued

prevent damage to test and operational combustion.

(U) $2,801 Develop advanced liquid engine combustion technology for improved performance while preserving chamber lifetime and reliability needs for engines used in heavy lift space vehicles. These efforts will be accomplished by full-scale single element cold flow injector testing in windowed pressure vessels, using laser diagnostics, and will characterize injector performance and reliability at high pressures and the development of a subscale hot fire experiment apparatus. The result of these efforts will be a flexible, low-cost subscale screening of candidate injector designs while preserving chamber lifetime and reliability requirements and goals, thereby reducing the cost by 2X of injector development to industry and government.

(U) $3,539 Continue to develop advanced material technology for lightweight components and material property enhancements for use in launch and space systems. Complete development of low-cost, high temperature, non-erosive, lightweight, coated carbon-carbon ceramic and hybrid polymer components for use in solid rocket space launch and missile motors. Develop processes required to apply the materials to liquid-propellant rocket production for dramatic weight reductions and transition design and processing techniques for high-strength, low-weight engine and motor components (metal and non-metal).

(U) $14,175 Continue to develop propulsion component technology for reliable, safe, and low-cost boost and orbit transfer systems. Continue developing and demonstrating advanced materials for rocket engine components and continue to develop turbomachinery, combustion devices, and propellant management devices for solid and liquid rockets. Begin development of high temperature oxygen rich turbine materials for applications to oxidizer rich turbomachinery. Begin application of advanced Aluminum Metal Matrix Composite Materials to rocket turbomachinery housings and rocket structural hardware. Complete testing of a high-performance, low-cost cryogenic upper stage combustion chamber for an expander cycle application. Complete the testing of a high performance hydrostatically supported liquid hydrogen. Continue characterizing new refractory combustion materials and devices to apply to liquid-propellant rocket engines with dramatic weight reductions. Continue to develop design and processing techniques for high-strength, low-weight engine and motor components (metals and non-metals). Initiate development of advanced lightweight rocket engine nozzle for upper stage and space booster applications. Verify performance and weight improvements of rapid densification nozzle technology using improved strategic propellants for future ballistic missiles. Continue to develop liquid oxidizer for hybrid propulsion technologies for space boosters and air launched missiles.

(U) $3,845 Continue developing solar electric propulsion technologies for stationkeeping, repositioning, and orbit transfer appropriate for large communication satellites and satellite constellations. Continue Hall thruster development to higher powers to meet Air Force need for Low Earth Orbit/Geosynchronous Orbit orbit transfers using electric propulsion. Complete development of propulsion for Air Force small satellites (~100 kg). Continue development of propulsion systems for micro-satellites (<25 kg) needed for advanced Air Force imaging missions. Continue the design and test of solar thrusters and concentrators for future orbit transfer systems and satellite propulsion systems with longer life.

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BUDGET ACTIVITY 02 - Applied Research	PE NUMBER AND TITLE 0602601F Space Technology	PROJECT 621011

(U) A. Mission Description Continued

(U) FY 2000 ($ in Thousands) Continued

(U)	$2,300	Continue the development of analytical tools for prediction of propellant life. Complete development of tools to increase the capability to determine the age life of strategic systems and other solid rocket motors.
(U)	$2,000	Continue development of Post Boost Control Systems for sustainment of current Intercontinental Ballistic Missile (ICBM) fleet. Continue development of compatible case/liner, insulator, and case systems for higher combustion temperature propellants. Complete design and begin fabrication of solid rocket motor test hardware. Fabricate and test gas generator with non-refractory materials capable of withstanding high heat loads. Develop technologies that are readily available over the life of strategic systems, which may also be potentially advantageous to the development of the next generation strategic systems..
(U)	$1,200	Continue development of missile propulsion technology for sustainment of current ICBM fleet. Complete design solid rocket motor test hardware.
(U)	$2,800	Continue the development of propulsion technologies for the Integrated High Payoff Rocket Propulsion Technology (IHPRPT) program. Complete the design efforts to minimize weight while significantly improving heat transfer capability of a high pressure thrust chamber assembly.
(U)	$2,300	Continue development of tactical missile propulsion systems. Complete fabrication of hybrid tactical oxider system for integration into test hardware. The fuel system will be developed in coordination with Japan.
(U)	$1,700	Continue the development of advanced upperstage and orbit transfer propulsion. Complete the design and fabrication of advanced solar thermal propulsion test hardware. Integrate propulsion components with system level components in preparation for space flight.
(U)	$41,600	Total

(U) FY 2001 ($ in Thousands)

(U)	$0	Efforts transferred to PE 0602203F, Project 624847.
(U)	$0	Total

(U) B. Project Change Summary

Not Applicable.

(U) C. Other Program Funding Summary ($ in Thousands)

(U) Related Activites:
(U) PE 0602111N, Anti-Air/Anti-Surface Warfare Technology.
(U) PE 0602303A, Missile Technology.
(U) PE 0603302F, Space and Missile Launch Technology.

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BUDGET ACTIVITY	PE NUMBER AND TITLE	PROJECT
02 - Applied Research	0602601F Space Technology	621011

(U) C. Other Program Funding Summary ($ in Thousands)

(U) PE 0603311F, Ballistic Missile Technology.

(U) PE 0603401F, Advanced Spacecraft Technology.

(U) This project has been coordinated through the Reliance process to harmonize efforts and eliminate duplication.

(U) D. Acquisition Strategy

Not Applicable.

(U) E. Schedule Profile

(U) Not Applicable.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2A Exhibit)

DATE: February 2000

BUDGET ACTIVITY: 02 - Applied Research

PE NUMBER AND TITLE: 0602601F Space Technology

PROJECT: 623326

COST ($ in Thousands)	FY 1999 Actual	FY 2000 Estimate	FY 2001 Estimate	FY 2002 Estimate	FY 2003 Estimate	FY 2004 Estimate	FY 2005 Estimate	Cost to Complete	Total Cost
623326 Lasers and Imaging Technology	15,614	19,039	0	0	0	0	0	Continuing	TBD

(U) A. Mission Description

This project examines the technical feasibility of moderate to high power lasers, associated optical components, and long-range optical imaging concepts required for Air Force missions. Technologies researched include advanced, short-wavelength laser devices for application as illuminators and imaging sources as well as advanced optical imagers for target identification and assessment. Laser technologies will be studied for their utility in aimpoint selection, target maintenance, and damage assessment. Additionally, high power solid state and chemical laser devices, optical components, advanced beam control and atmospheric compensation technologies, techniques for laser target vulnerability assessments, and nonlinear optical processes and techniques are developed.

(U) FY 1999 ($ in Thousands)

(U)	$1,025	Developed generic, high energy laser technologies for applications such as illuminators and use in wavelength-specific military missions.
(U)	$3,040	Developed long-range optical technologies for increased resolution, characterization, and data fusion to support missions such as space object identification and ground target identification from space.
(U)	$1,486	Investigated and developed advanced laser transceiver systems, and advanced data collection and processing algorithms for light detection and ranging (LIDAR) remote sensing of atmospheric properties, chemical agents, and target effluents.
(U)	$2,854	Developed laser source and target coupling technology for next-generation high-payoff applications such as damage/destroy countermeasures against infrared imaging seekers.
(U)	$588	Investigated and developed nonlinear optics (NLO) technologies to support imaging and beam projection technologies.
(U)	$3,471	Developed high power solid state lasers/arrays at alternate wavelengths for applications such as forward looking infrared (FLIR) systems and infrared (IR) missile jamming, chemical agent detection, illuminators, efficient semiconductor laser array pumping modules, and disrupt/jam countermeasures against near-term threats.
(U)	$3,150	Developed spatially coherent lasers for tactical/unmanned air vehicle and space applications such as designation/illumination and remote sensing which require higher power sources.
(U)	$15,614	Total

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(U) A. Mission Description Continued

(U) FY 2000 ($ in Thousands)

(U)	$1,892	Develop long-range optical technologies for increased resolution characterization and data fusion applications. Lightweight deployable mirrors that are the critical basis for these applications will be demonstrated at the one-meter class size in the laboratory with holographic correction integrated into the test system. Issues associated with deployment schemes for the membrane mirrors will also be addressed.
(U)	$645	Continue development of nonlinear optics technologies to support imaging and beam projection applications such as relay mirrors. Nonlinear optics allows non-mechanical beam cleanup and mirror corrections with greatly decreased complexity. Laboratory efforts will concentrate on component development to obtain increased efficiency and resolution for scaling to large and higher power devices. Small scale tests and demonstrations of relay mirror components will be performed.
(U)	$3,633	Develop high power chemical and all-gas phase iodine laser technologies for applications such as directed energy weapons and illuminators. Demonstrate high energy, frequency conversion of chemical oxygen iodine laser (COIL) for potential airborne laser illuminator applications. Complete parallel technology efforts for the repetitively pulsed COIL illuminator. Evaluate these results and assess the potential of this technology for an alternate, scalable airborne laser illuminator. Improve efficiency and reduce weight of COIL devices for airborne laser missions. Develop with proof of principle experiments advanced COIL technologies which include iodine atom production with electric discharges and iodine atom production through chemical reactions. Evaluate, theoretically and experimentally, advanced ejector nozzle concepts which improve the pressure recovery potential of COIL devices. Demonstrate a 100-watt subsonic all-gas phase chemical iodine laser.
(U)	$4,229	Develop laser source, beam control, and target coupling technologies to counter current and next generation air-to-air and surface-to-air missile threats to aircraft platforms. Develop compact, reliable, high-power, solid state laser technologies at mid-infrared wavelengths. Investigate new laser materials needed to reduce the size and weight (currently 40 pounds, one cubic foot) of solid state laser based infrared counter measure demonstrator. Develop a mid-infrared laser with the beam brightness needed for platforms with high infrared signatures. Investigate novel materials effects associated with plasma/spark and ultra-fast lasers for countering focal plane array seekers. Investigate propagation, beam control, and imaging technologies related to ultra-fast lasers.
(U)	$6,640	Develop low-cost, scalable, high power solid state laser architectures by integrating doped fiber lasers with diode-laser pump sources for directed energy applications such as unmanned aerial vehicle designators/imagers and next generation weapons applications such as space-based lasers and airborne lasers. Develop promising fiber laser technologies exhibiting attributes that will enable applications that require laser mobility such as low-cost, high efficiency (approaching 25%), compactness (10 milliwatts per cubic centimeter), and scalability. Develop integration technologies necessary for demonstration of power at 100s of Watts.
(U)	$800	Develop relay mirror concepts and pursue development of large optics and their optical compensation for large mirror space-based applications.
(U)	$1,200	Develop advanced laser remote optical sensing technology to support advanced standoff detection requirements for measurement and signature intelligence (MASINT), bomb damage assessment, target characterization, weapons of mass destruction, and theater intelligence, surveillance,

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BUDGET ACTIVITY 02 - Applied Research	PE NUMBER AND TITLE 0602601F Space Technology	PROJECT 623326

(U) A. Mission Description Continued

(U) FY 2000 ($ in Thousands) Continued

and reconnaissance. Complete Phase I experiments for frequency agile heterodyne receiver development. Establish transmitter/receiver requirements for unmanned aerial vehicle applications.

(U) $19,039 Total

(U) FY 2001 ($ in Thousands)

(U) $0 Program transferred to PE 0602605, Project 624866.

(U) $0 Total

(U) B. Project Change Summary

Not Applicable.

(U) C. Other Program Funding Summary ($ in Thousands)

(U) Related Activities:

(U) PE 0603319F, Airborne Laser Demonstrator.

(U) PE 0603605F, Advanced Weapons Technology.

(U) This project has been coordinated through the Reliance process to harmonize efforts and eliminate duplication.

(U) D. Acquisition Strategy

Not Applicable.

(U) E. Schedule Profile

(U) Not Applicable.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2A Exhibit)

DATE: February 2000

BUDGET ACTIVITY: 02 - Applied Research

PE NUMBER AND TITLE: 0602601F Space Technology

PROJECT: 624846

COST ($ in Thousands)	FY 1999 Actual	FY 2000 Estimate	FY 2001 Estimate	FY 2002 Estimate	FY 2003 Estimate	FY 2004 Estimate	FY 2005 Estimate	Cost to Complete	Total Cost
624846 Spacecraft Payload Technologies	0	0	8,395	11,785	10,499	9,866	13,918	Continuing	TBD

(U) A. Mission Description

This project develops advanced technologies for spacecraft payload operations. The project focuses on three primary areas: (1) development of advanced, space-qualified, survivable electronics, and electronics packaging technologies; (2) research and improvement of advanced space data generation and exploitation technologies, including infrared, Fourier Transform hyperspectral imaging, and satellite antenna subsystem technologies; and (3) creation of high fidelity space simulation models to support space-based surveillance and space asset protection research and development for the warfighter.

(U) FY 1999 ($ in Thousands)

(U) $0 Previously accomplished in Project 628809.

(U) $0 Total

(U) FY 2000 ($ in Thousands)

(U) $0 Previously accomplished in Project 628809.

(U) $0 Total

(U) FY 2001 ($ in Thousands)

(U) $2,872 Develop advanced space infrared technologies, hardened focal plane detector arrays, and quantum well infrared photodetectors (QWIPs) to enable acquisition, tracking, and discrimination of hot targets, as well as 'cold body' targets such as decoys, satellites, and midcourse warheads. Design low temperature multicolor and low background infrared detectors and QWIPs, higher temperature infrared detectors, and higher performance radiation hardened detectors. Continue development of two-, three-, and multi-color detectors, and tunable and broadband gratings. Develop longer wavelength infrared detectors, mid-wavelength infrared detectors for higher temperature operation, and infrared detectors with optimal background-limited performance for stressing, low photon noise, space backgrounds.

(U) $812 Develop hyperspectral imaging data exploitation methodologies for military remote sensing applications with the Fourier Transform HyperSpectral Imager (FTHSI). The FTHSI payload will demonstrate the capability of providing the warfighter data concerning terrain categorization, feature extraction, geological formation mapping, and trafficability within an area observed from space. Complete analysis of the hyperspectral imaging data received from the FTHSI payload. Complete assembly of data images for target identification and image evaluation for commercial and military purposes.

(U) $3,878 Continue to develop technologies for space-based payload components such as low power, high performance, radiation hardened electronic devices, micro-electro-mechanical system (MEMS) devices, and advanced electronics packaging for next generation high performance space

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(U) A. Mission Description Continued

(U) FY 2001 ($ in Thousands) Continued

electronics. Goals are decreased feature size, improved scalability, decreased size/weight /power, and radiation hardness. Continue characterizing microelectronic materials and internal structures and apply results to improve fabrication processes. Design next-generation low-power, quantum-sized devices such as high-speed, radiation-hardened, low-power alternatives for space applications. Fabricate improved radiation-hardened nonvolatile memories, processors, sensors, and analog devices. Fabricate ultra-high density, low-power MEMS device for evaluation in space environment. Fabricate smaller, lighter, lower power electronics packaging.

(U) $833 Continue to develop modeling, simulation, and analysis (MS&A) tools for space-based surveillance systems, optical/infrared imaging space systems, large deployable space optics, and distributed satellite architecture payloads. MS&A tools provide data and validate research and development systems engineering level technology trade off decisions for space-based missions/campaign level assessments and for intelligent satellite system testbeds. Integrate simulation architecture models using visual programming codes and commercial-off-the-shelf software to enhance fidelity of satellite constellation-level modeling. Interconnect satellite toolkit, spacecraft simulation toolkit, and weather and space simulation software into one framework. Demonstrate multi-satellite constellations and distributed satellite cluster models in simulation testbed.

(U) $8,395 Total

(U) B. Project Change Summary

Not Applicable.

(U) C. Other Program Funding Summary ($ in Thousands)

(U) Related Activities:

(U) PE 0603401F, Advanced Spacecraft Technology.

(U) This project has been coordinated through the Reliance process to harmonize efforts and eliminate duplication.

(U) D. Acquisition Strategy

Not Applicable.

(U) E. Schedule Profile

(U) Not Applicable.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2A Exhibit)

DATE: February 2000

BUDGET ACTIVITY: 02 - Applied Research

PE NUMBER AND TITLE: 0602601F Space Technology

PROJECT: 625797

COST ($ in Thousands)	FY 1999 Actual	FY 2000 Estimate	FY 2001 Estimate	FY 2002 Estimate	FY 2003 Estimate	FY 2004 Estimate	FY 2005 Estimate	Cost to Complete	Total Cost
625797 Advanced Weapons and Survivability Technology	14,730	18,530	0	0	0	0	0	Continuing	TBD

(U) A. Mission Description

High power microwave (HPM) and other unconventional weapon concepts using innovative technologies are explored in this project. Technologies that support a wide range of Air Force missions such as suppression of enemy air defenses, command and control warfare, and vehicle self-protection are developed. This project provides for vulnerability assessments of representative U.S. strategic and tactical systems to directed energy weapons, directed energy weapon technology assessment for specific Air Force missions, and directed energy weapon lethality assessments against foreign targets. In addition to directed energy weapon threats, this project conducts assessments of specific space environmental (natural and man-made) effects on space systems and develops hardening technologies and methodologies.

(U) FY 1999 ($ in Thousands)

(U) $6,048 Developed generic advanced weapon technologies that support multiple Air Force applications such as command and control warfare and suppression of enemy air defenses.

(U) $3,979 Assessed effects/lethality of directed energy weapon technologies against representative air and ground military systems.

(U) $1,397 Developed HPM technologies that will support applications such as command and control warfare.

(U) $1,583 Developed HPM technologies that will support applications such as suppression of enemy air defenses.

(U) $1,723 Assessed the vulnerability of various space assets to threats such as solar radiation, space debris, and directed energy weapons.

(U) $14,730 Total

(U) FY 2000 ($ in Thousands)

(U) $1,498 Investigate technologies for developing innovative HPM sources to support multiple Air Force applications such as command and control warfare and suppression of enemy air defenses. Conduct field test for single shot HPM device. Design, build, and test candidate repetitive device. Obtain experimental data to improve anchoring of existing computer models.

(U) $1,977 Assess effects/lethality of directed energy weapon technologies against representative air and ground military systems. Investigate susceptibility of current fighter technologies and provide results to developers. Complete lethality assessment studies on selected military relevant targets. Continue to identify HPM protection requirements on large and small aircraft.

(U) $1,800 Develop wideband HPM technologies that will support command and control warfare applications. Research methods to enhance HPM source technology such as power throughput for solid state switches and high repetition rates for high pressure gas switches. Extend the current capabilities of electromagnetic modeling and simulation codes to better predict the electromagnetic environment induced in more complex geometric structures.

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(U) A. Mission Description Continued

(U) FY 2000 ($ in Thousands) Continued

(U)	$2,646	Develop narrowband high power microwave (HPM) technologies that will support suppression of enemy air defenses. Develop models of HPM effects for military electronic targets of interest. Validate and verify the models through measurement and computer simulation. Assess predictability of models. Determine those HPM effects parameters enhanced through repetitively pulsing. Design and develop component technologies - prime power, pulsed power, sources, and antennas - for repetitively pulsed systems.
(U)	$5,561	Investigate HPM technologies that will support offensive and defensive advanced airborne tactical applications made possible based on increased power available on future aircraft. Establish the technical feasibility of the concepts that are emerging from the Directed Energy Applications in Tactical Aircraft Combat (DE ATAC) study by gathering the appropriate HPM effects data and investigating the feasibility of the source technology specification set for each concept. Investigate a wide range of technology alternatives and lethality parameters and use this data in a trade off study to select the most promising concepts that optimizes performance, cost, and schedule.
(U)	$571	Investigate Active Denial Technology applications for Agile Combat Support. Develop high specific power, millimeter-wave sources using computer simulation and experiments.
(U)	$1,977	Assess the vulnerability of six U.S., NATO, and foreign satellites to the effects of directed energy weapons, primarily high energy lasers and HPMs. Previous assessments will be updated, as required, based on new intelligence information. Other directed energy effects will be included as appropriate.
(U)	$2,500	Evaluate radio frequency threats to U.S. infrastructure.
(U)	$18,530	Total

(U) FY 2001 ($ in Thousands)

(U)	$0	Program transferred to PE 0602605, Project 624867.
(U)	$0	Total

(U) B. Project Change Summary

Not Applicable.

(U) C. Other Program Funding Summary ($ in Thousands)

(U) Related Activities:

(U) PE 0602202F, Human Systems Technology.

(U) PE 0603605F, Advanced Weapons Technology.

(U) This project has been coordinated through the Reliance process to harmonize efforts and eliminate duplication.

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(U) D. Acquisition Strategy

Not Applicable.

(U) E. Schedule Profile

(U) Not Applicable.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2A Exhibit)

DATE: February 2000

BUDGET ACTIVITY: 02 - Applied Research

PE NUMBER AND TITLE: 0602601F Space Technology

PROJECT: 628809

COST ($ in Thousands)	FY 1999 Actual	FY 2000 Estimate	FY 2001 Estimate	FY 2002 Estimate	FY 2003 Estimate	FY 2004 Estimate	FY 2005 Estimate	Cost to Complete	Total Cost
628809 Spacecraft Vehicle Technologies	33,881	45,256	31,002	31,064	33,603	36,604	37,749	Continuing	TBD

(U) A. Mission Description

This project focuses on seven major space and missile technology areas: spacecraft platforms (e.g., structures, controls, power, and thermal management); space-based payload (e.g., survivable electronics); satellite control (e.g., software for autonomous distributed satellite formation flying, signal processing, and control); modeling and simulation of space-based systems; satellite protection technologies (e.g., space environment effects, debris prediction, and threat warning/attack reporting); microsatellite technologies; and integrated experiments of advanced technologies for transition to planned systems (e.g., payload/platform/launch vehicle merging).

(U) FY 1999 ($ in Thousands)

(U) $3,862 Developed technologies for space platform subsystems such as cryocoolers, space vehicle thermal management, compact, high efficiency solar power cells, lightweight batteries, and innovative power generation and storage concepts.

(U) $3,796 Developed technologies for space platform structures such as spacecraft structural controls for vibration suppression, multifunctional structures, and lightweight composite satellite and launch vehicle structures.

(U) $3,199 Developed technologies for space-based payload subsystems such as advanced infrared sensors, advanced hardened focal plane detector arrays, and antenna architectures for a space-based radar Air Moving Target Indication (AMTI) capability.

(U) $4,023 Developed technologies for space-based payload components such as low power, high performance, radiation hardened electronic devices, micro-electro-mechanical systems (MEMS) devices, and advanced electronics packaging.

(U) $1,862 Developed technologies and software for autonomous distributed satellite formation flying, signal processing, and control. Developed modeling and simulation applications for space-based surveillance systems.

(U) $1,160 Completed space environmental effects migration and space debris prediction satellite protection technology development efforts. Delivered mission operations and orbit control software, and orbit and orbital debris analyses for use in operations planning and operation of satellite flight demonstrations.

(U) $8,891 Developed ground and small satellite integration technologies for deployable large aperture optical arrays and spaceborne platforms with advanced bus components and standardized interfaces for testing and demonstrating revolutionary high payoff mission hardware and mission-enabling technologies for space and near-space experiments. Launched the MightySat I vehicle and demonstrated operation of the integrated platform and stand-alone experimental payloads.

(U) $3,203 Developed microsatellite (10-100kg) technologies and integrated microsatellite technology concepts for collaborative microsatellite constellations to support applications such as near-earth object inspection.

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BUDGET ACTIVITY 02 - Applied Research	PE NUMBER AND TITLE 0602601F Space Technology	PROJECT 628809

(U) A. Mission Description Continued

(U) FY 1999 ($ in Thousands) Continued

(U)	$3,885	Conducted Phase III of the Terabit fiber optic technology program.
(U)	$33,881	Total

(U) FY 2000 ($ in Thousands)

(U)	$5,780	Develop technologies for advanced space platform subsystems such as cryocoolers, space vehicle thermal management, compact, high efficiency solar power cells, lightweight batteries, and innovative power generation and storage concepts. Advanced space platform subsystems will have more available power, longer operational lifetimes and increased operational range, and will be lighter and more affordable than current subsystems. Start development of 35% efficient solar cells and polymer batteries. Continue development of thin film solar cells, lithium-ion batteries, and thermal to electric conversion cells. Continue development of non-electrochemical energy storage techniques.
(U)	$7,166	Develop technologies for advanced space platform structures such as spacecraft structural controls for vibration suppression, multifunctional structures, deployable large aperture optical arrays, and lightweight composite satellite and launch vehicle structures. Whole spacecraft and launch vibration suppression will enable precision pointing and sensing systems. Multifunctional and composite structures, with a higher level of integration and standardized interfaces will be reusable, lighter, and more affordable. Deployable large aperture optical arrays will enable continuous space-based battlefield surveillance. Design vibration suppression systems for primary and secondary payloads. Continue development of design and integration techniques for multifunctional structures and integration of multi-chip modules into spacecraft bus. Develop and fabricate component subsystems for deployable large aperture optical arrays.
(U)	$4,367	Develop technologies for space-based payload components such as low power, high performance, radiation hardened electronic devices, micro-electro-mechanical system (MEMS) devices, and advanced electronics packaging for next generation high performance space electronics. Goals are decreased feature size, improved scalability, decreased size/weight/power, and radiation hardness. Characterize microelectronic materials and internal structures to improve fabrication processes. Characterize next-generation low-power, quantum-sized devices for possible space application. Design devices such as improved radiation-hardened nonvolatile memories, processors, sensors, and analog devices. Design ultra-high density, low-power MEMS device for evaluation in space environment. Design smaller, lighter, lower power electronics packaging.
(U)	$1,807	Develop modeling, simulation, and analysis (MS&A) tools for space-based surveillance systems, optical/infrared imaging space systems, large deployable space optics, and distributed satellite architecture payloads. MS&A tools provide data and validate research and development systems engineering level technology trade off decisions for space-based missions/campaign level assessments and for intelligent satellite system testbeds. Integrate simulation architecture models using visual programming codes and commercial-off-the-shelf software to enhance fidelity of satellite constellation-level modeling.
(U)	$3,232	Develop key satellite threat warning technologies and tools for on-board satellite use to detect, geolocate, and characterize acquired intentional and unintentional ground-based radio frequency and laser signals. Satellite threat warning technologies enable the warfighter to increase

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(U) A. Mission Description Continued

(U) FY 2000 ($ in Thousands) Continued

knowledge of possible hostile acts directed at mission critical satellites and aid in satellite anomaly resolution. Characterize technologies to determine whether hostile acts or the space environment are affecting critical warfighter mission satellites, discriminating between environmental/radiation effects, radio frequency interference, and laser signals. Develop methodology for determining signal information necessary for source evaluation and nature.

(U) $6,420 Develop ground support and small satellite integration technologies for spaceborne platforms with advanced bus components and standardized interfaces for testing and demonstrating revolutionary high payoff mission hardware and mission-enabling technologies for space and near-space experiments. The small experimental satellites provide an affordable, adaptable space platform as an orbiting 'lab-bench' to test high payoff, high risk mission hardware and reduce risk of further development by demonstrating proof-of-concept. Launch the MightySat II.1 vehicle and demonstrate operation of the integrated platform and stand-alone experimental payloads.

(U) $7,110 Develop microsatellite (10-100kg) technologies and integrated microsatellite technology concepts. This new class of small, highly capable satellites can reduce life cycle costs by as much as 90 percent and enables new space missions and architectures such as reconfigurable, multi-mission microsatellite formations for sparse aperture sensing, precise geolocation, secure communications, near-earth object inspection, and remote satellite servicing. Complete development of first microsatellite in the series to test autonomous microsatellite operations. Design microsatellite for a three unit constellation to demonstrate on-orbit formation flying, inter-satellite communications, distributed processing, and sparse aperture sensing

(U) $4,440 Develop hyperspectral imaging technologies for space-borne assets to provide improved capabilities for the warfighter in target detection, terrain classification, and related surveillance applications. Develop Warfighter-1 target detection and terrain classification algorithms and perform on-orbit evaluation of the hyperspectral sensor and ground operations. Complete integration and testing of data processing and exploitation algorithms for the Fourier Transform Hyperspectral Imaging sensor and validate results with baseline data. Develop an advanced hyperspectral processing and data exploitation center for developing and validating hyperspectral imaging algorithms.

(U) $4,934 Continue the terabit technology program, focusing on increasing the channel capability and improving the bit error rate. Extend the range of the wireless 28GHz link.

(U) $45,256 Total

(U) FY 2001 ($ in Thousands)

(U) $4,875 Continue to develop technologies for advanced space platform subsystems such as cryocoolers, space vehicle thermal management, compact, high efficiency solar power cells, lightweight batteries, and innovative power generation and storage concepts. Advanced space platform subsystems will have more available power, longer operational lifetimes and increased operational range, and be lighter and more affordable than current subsystems. Improve accuracy of cryocooler modeling tools, and identify mechanisms that limit operational life and degrade cryocooler

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(U) A. Mission Description Continued

(U) FY 2001 ($ in Thousands) Continued

subsystem performance. Continue development of 35% efficient solar cells, thin film solar cells, thermal to electric conversion, and lithium ion and polymer batteries.

(U) $6,176 Continue to develop technologies for advanced space platform structures such as spacecraft structural controls for vibration suppression, multifunctional structures, deployable large aperture optical arrays, and lightweight composite satellite and launch vehicle structures. Whole spacecraft and launch vibration suppression will enable precision pointing and sensing systems. Multifunctional and composite structures, with a higher level of integration and standardized interfaces will be reusable, lighter, and more affordable. Deployable large aperture optical arrays will enable continuous space-based battlefield surveillance. Develop and complete vibration suppression algorithms. Continue development of multifunctional structures and complete integration techniques. Integrate and ground test component subsystems of deployable large aperture optical arrays to identify performance of deployable optics.

(U) $2,346 Continue to develop ground support and small satellite integration technologies for spaceborne platforms with advanced bus components and standardized interfaces for testing and demonstrating revolutionary high payoff mission hardware and mission-enabling technologies for space and near space experiments. The small experimental satellites provide an affordable adaptable space platform as an orbiting 'lab-bench' to test high payoff, high risk mission hardware and reduce risk of further development by demonstrating proof-of-concept. Conduct MightySat II.1 mission operations and analyze platform and stand-alone experiment operations.

(U) $17,605 Continue to develop microsatellite (10-100kg) technologies and integrated microsatellite technology concepts. This new class of small, highly capable satellites can reduce life cycle costs by as much as 90 percent and enables new space missions and architectures such as reconfigurable, multi-mission microsatellite formations for sparse aperture sensing, precise geolocation, secure communications, near-earth object inspection, and remote satellite servicing. Fabricate and test prototype microsatellite, and begin fabrication of a three flight unit constellation to demonstrate on-orbit formation flying, inter-satellite communications, distributed processing, and sparse aperture sensing.

(U) $31,002 Total

(U) B. Project Change Summary

Not Applicable.

(U) C. Other Program Funding Summary ($ in Thousands)

(U) Related Activities:

(U) PE 0602203F, Aerospace Propulsion.

(U) PE 0602102F, Materials.

(U) PE 0603302F, Space and Missile Rocket Propulsion.

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(U) C. Other Program Funding Summary ($ in Thousands)

(U) PE 0603311F, Ballistic Missile Technology.
(U) PE 0603401F, Advanced Spacecraft Technology.
(U) PE 0603410F, Space Systems Environmental Interactions.
(U) This project has been coordinated through the Reliance process to harmonize efforts and eliminate duplication.

(U) D. Acquisition Strategy

Not Applicable.

(U) E. Schedule Profile

(U) Not Applicable.